Real time Satellite Estimation and Mapping of Snow Water Equivalent across the Sierra Nevada

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CA Drought

2/26/2014

Remotely sensed snowpack reconstruction improves Sierra Nevada water storage estimates

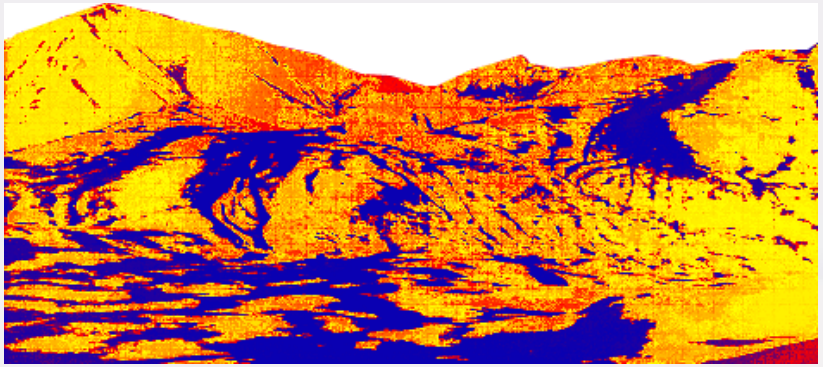
$$SWE_n = SWE_0 - \sum_{j=1}^{n} M_j$$

when $SWE_n = 0$,

$$SWE_0 = \sum_{j=1}^{n} M_j$$

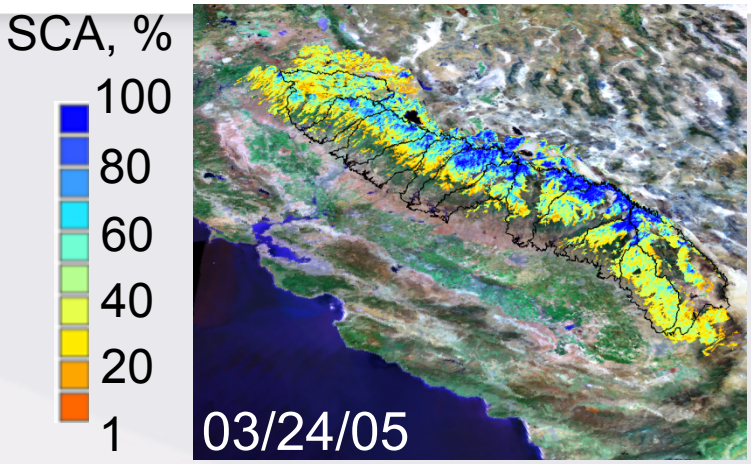
snow covered area

daily snowmelt, cm



Cline et al., 1998a,b; Liston, 1999; Molotch et al., 2004b; Molotch & Bales, 2005;2006; Durand et al., 2007; Molotch, 2008.

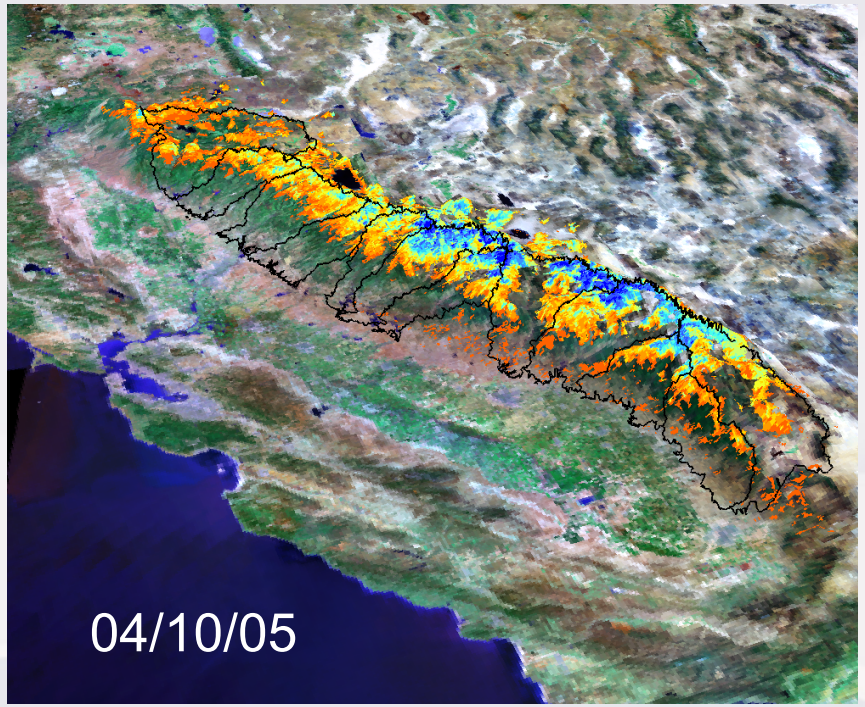
Range-Scale Snow Cover: MODIS



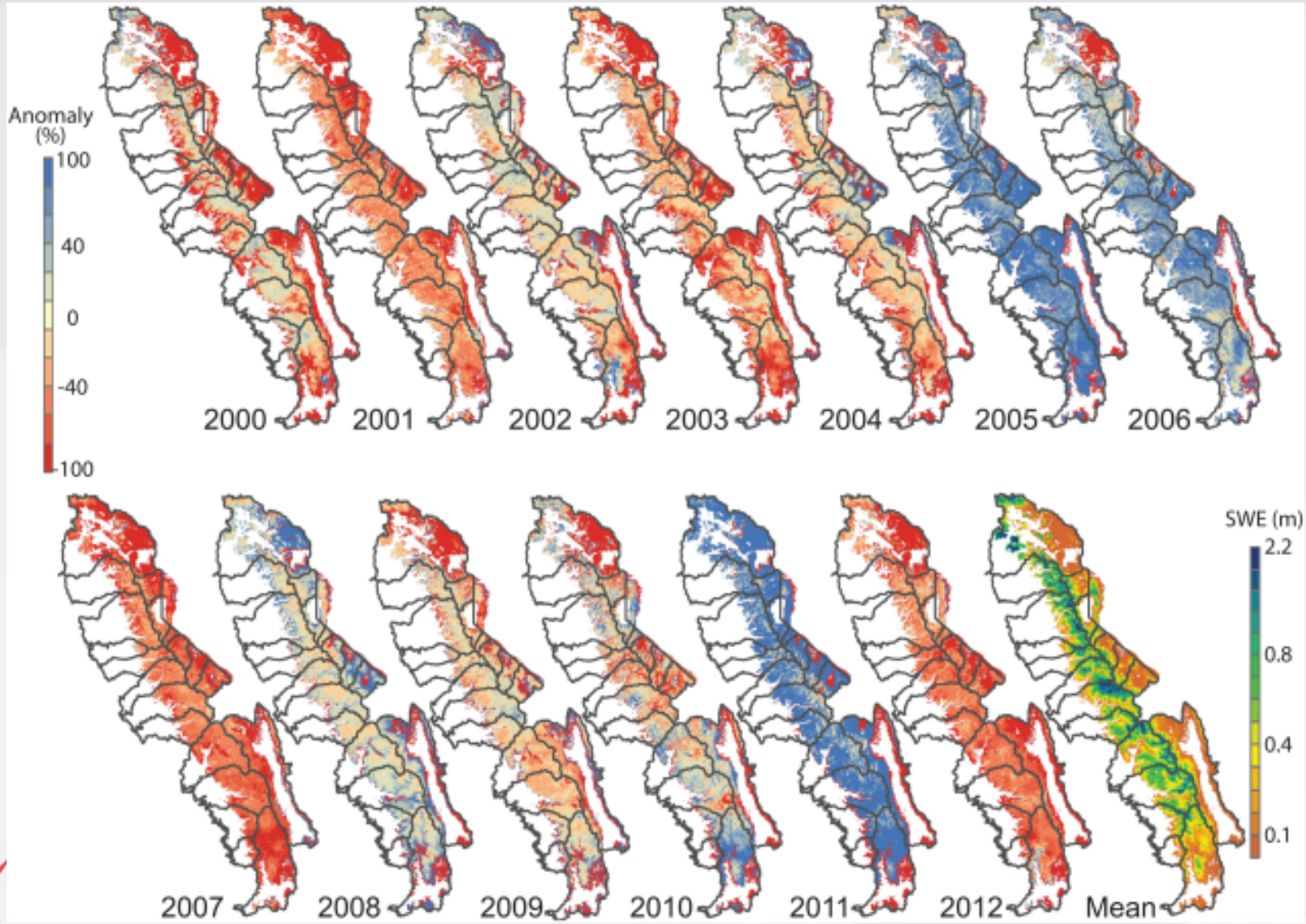
MODSCAG – Dozier et al., 2010

Due to lower initial mass snow disappeared rapidly in N. Sierra.

Areas with persistent snow cover had greatest mass.

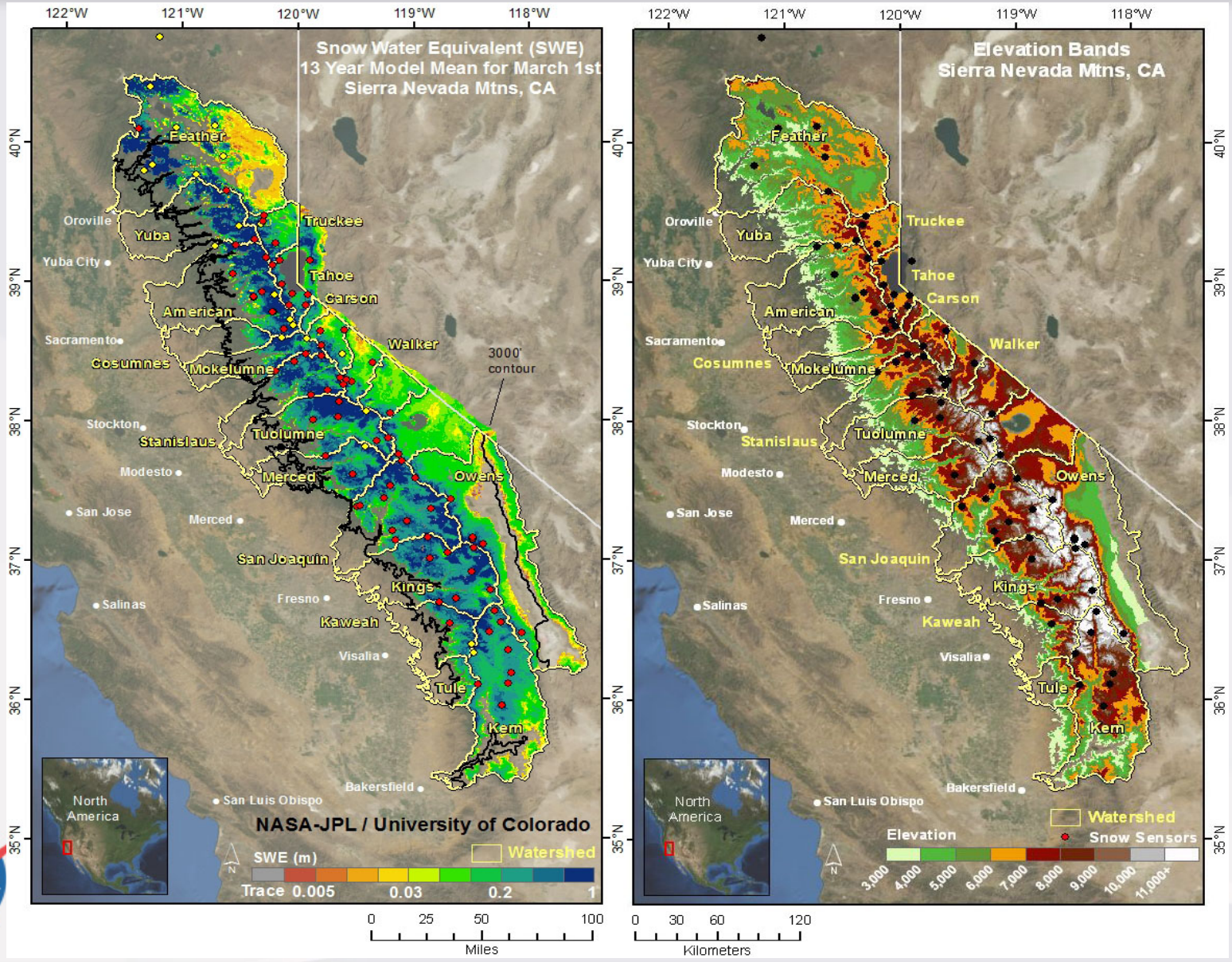


Snow Water Equivalent Anomalies



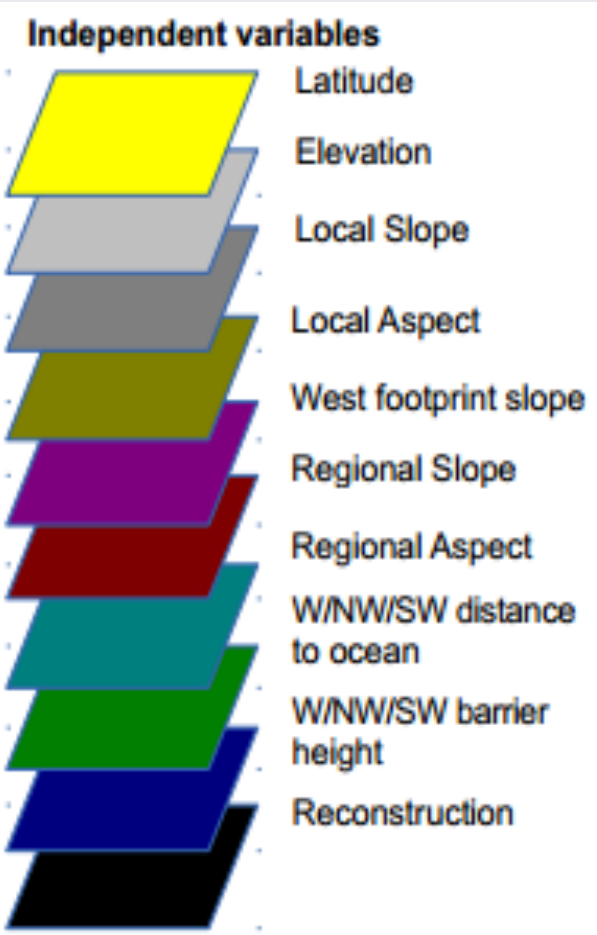
Guan, Molotch, et al., 2013 – Water Resources Research

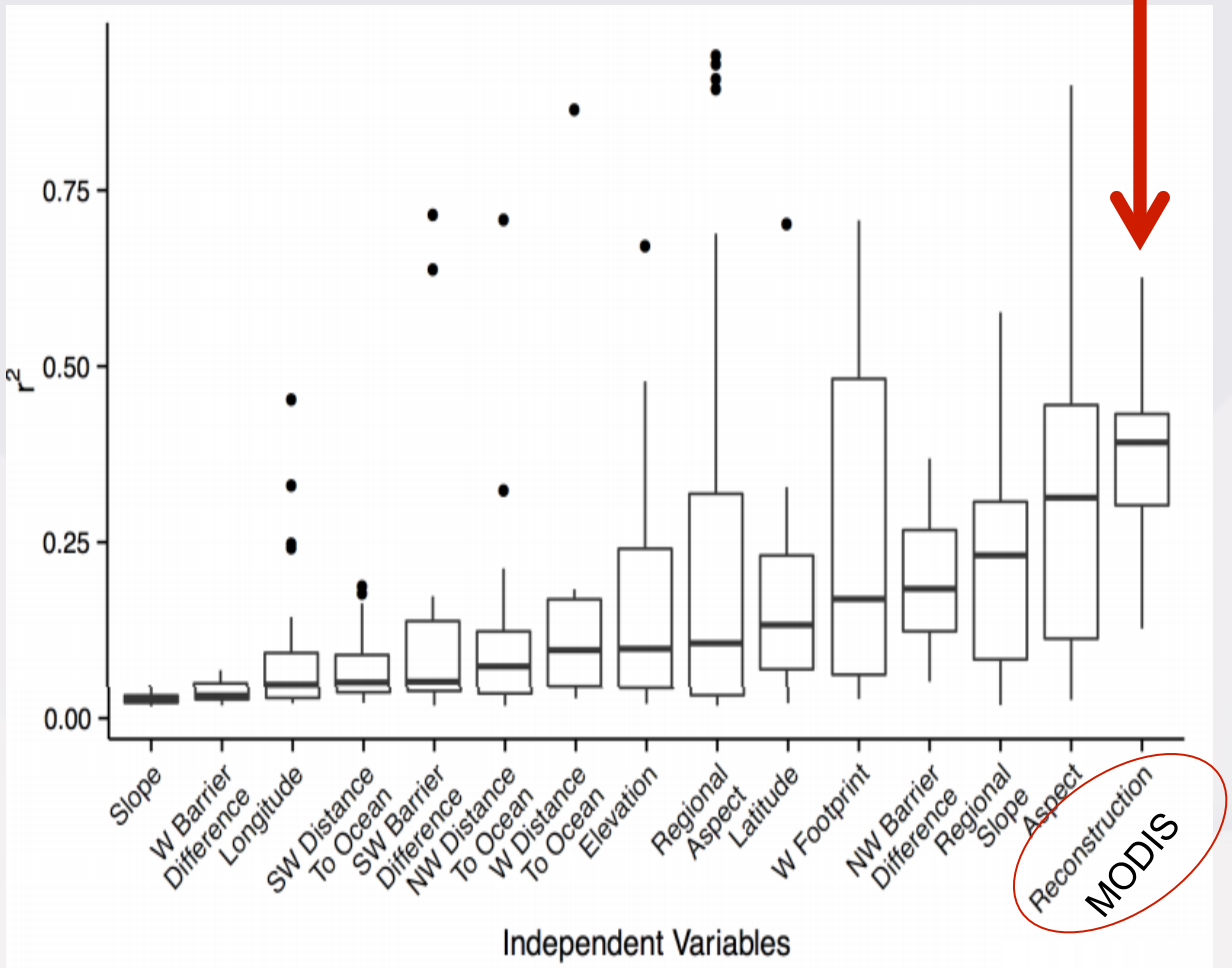
Blending Reconstruction w/ Snow Sensors



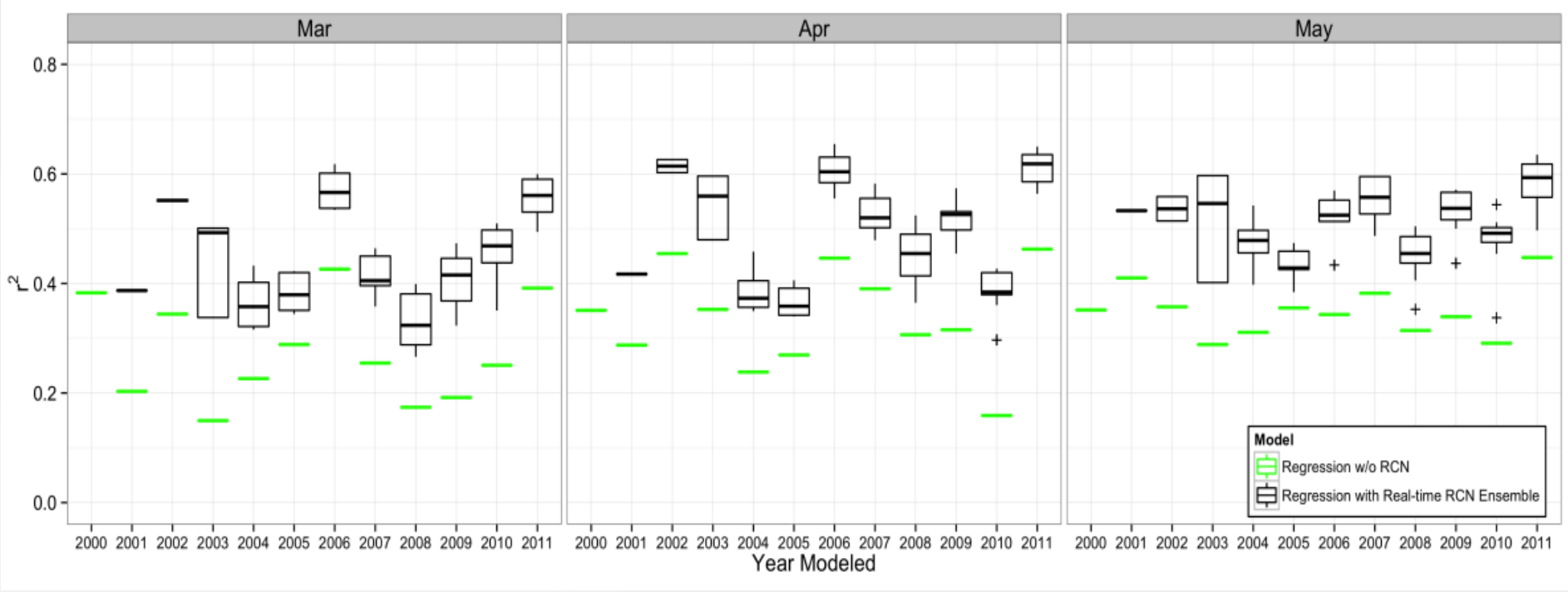
Correlation between SWE & Terrain

Highest correlation



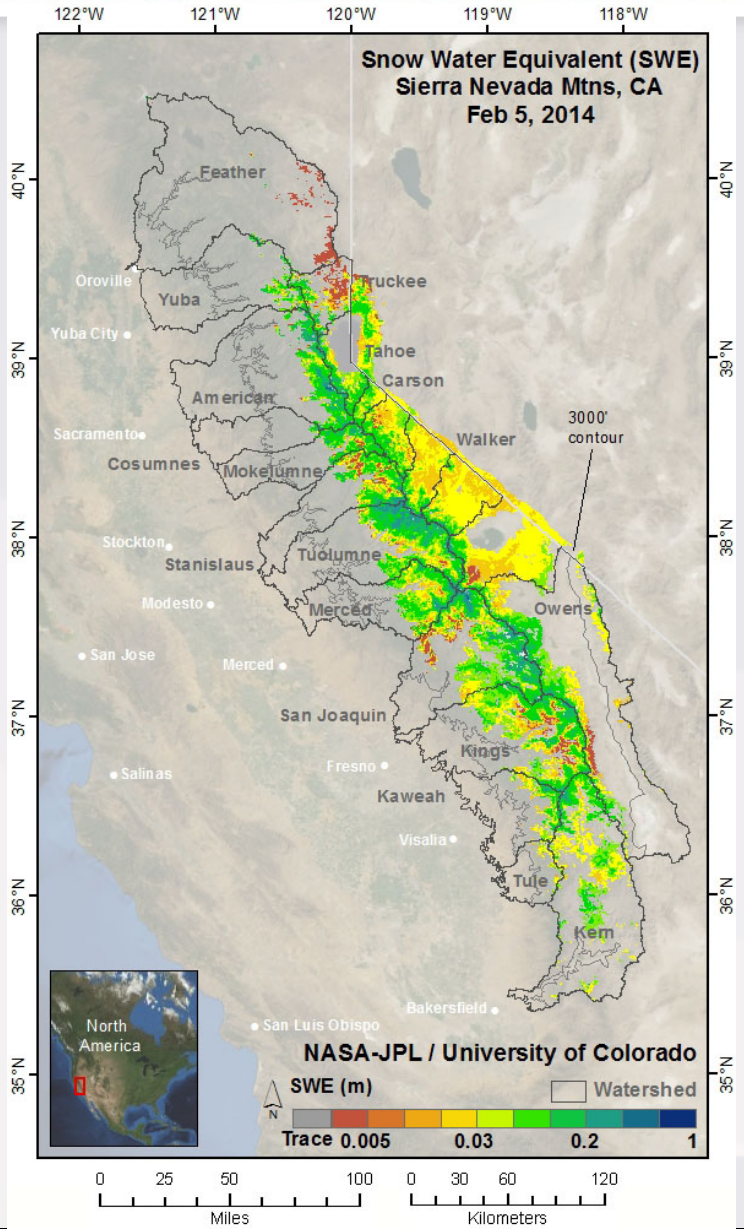


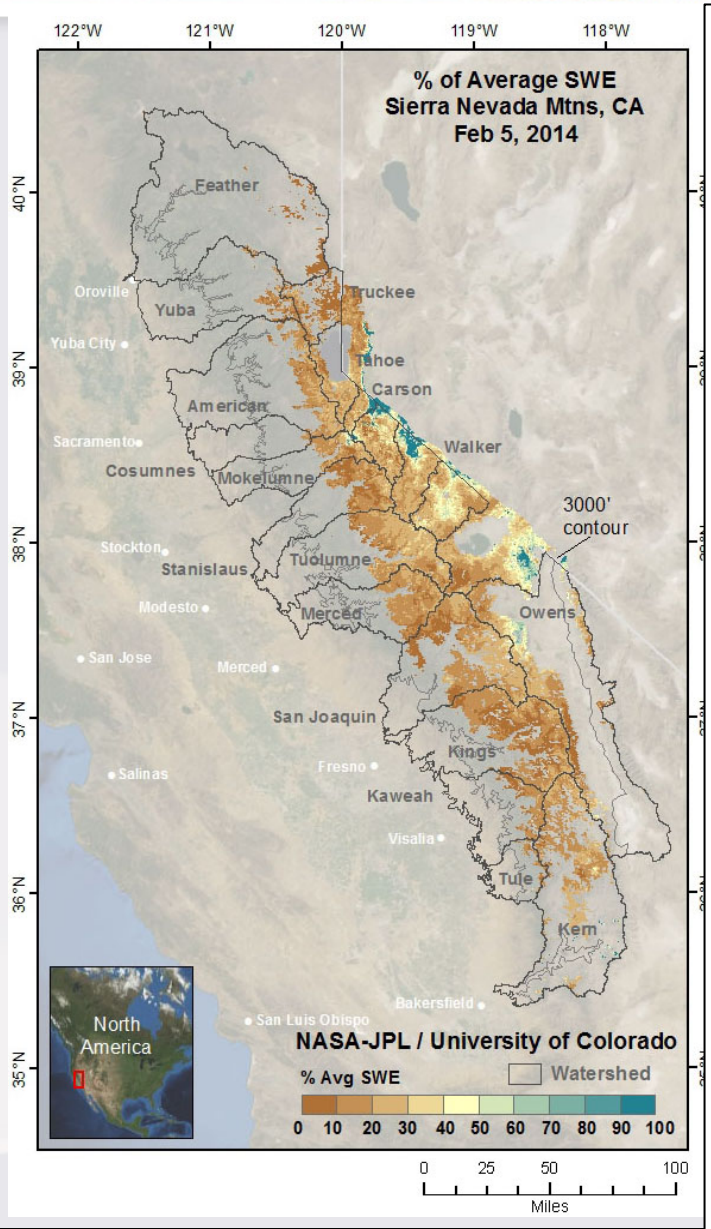
Multi-variate Regression: SWE Interpolation



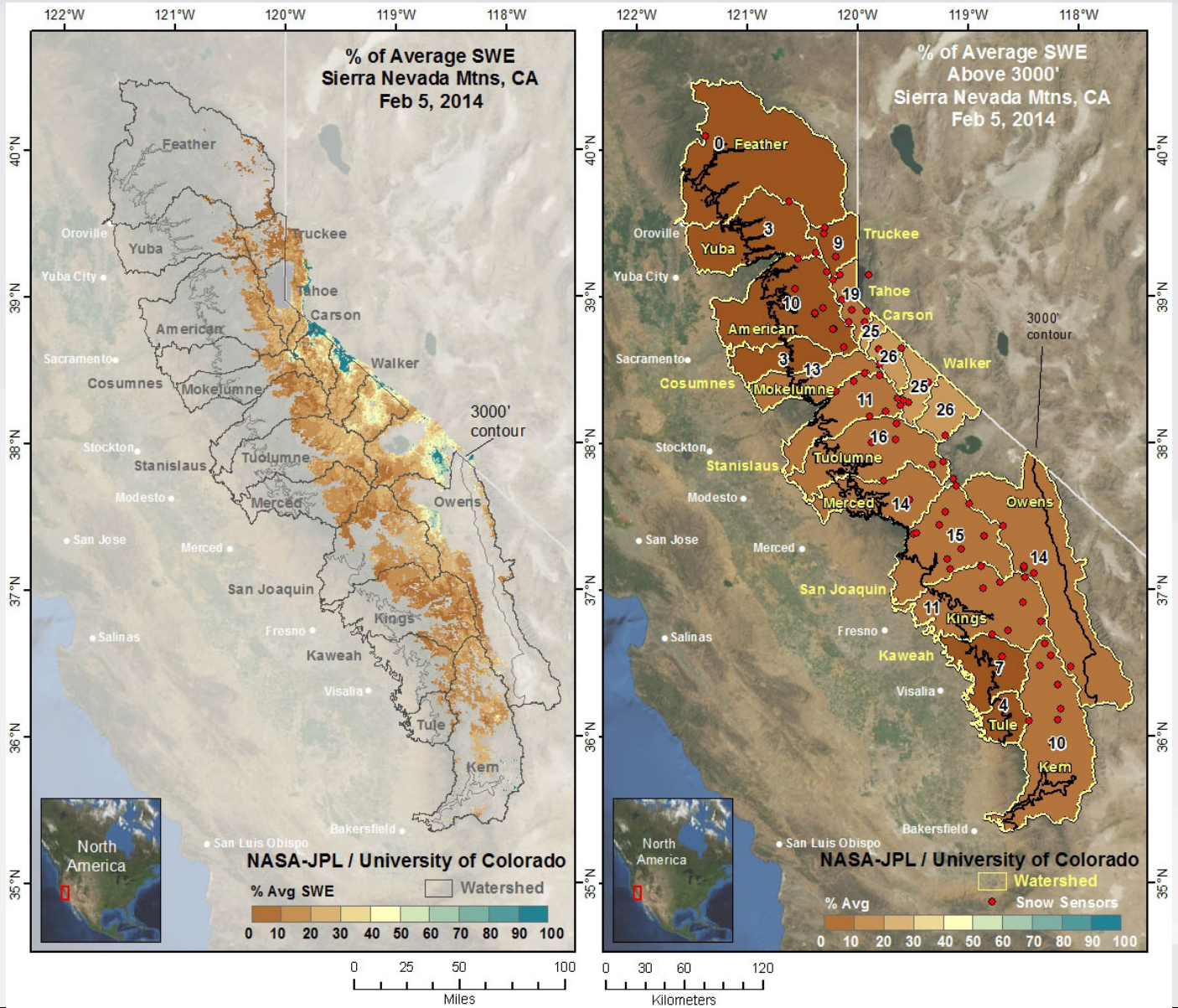
R^2 increase = 0.18 R^2 increase = 0.16 R^2 increase = 0.16

Real Time SWE: February 5, 2014





Real Time SWE Anomaly: Feb. 5, 2014



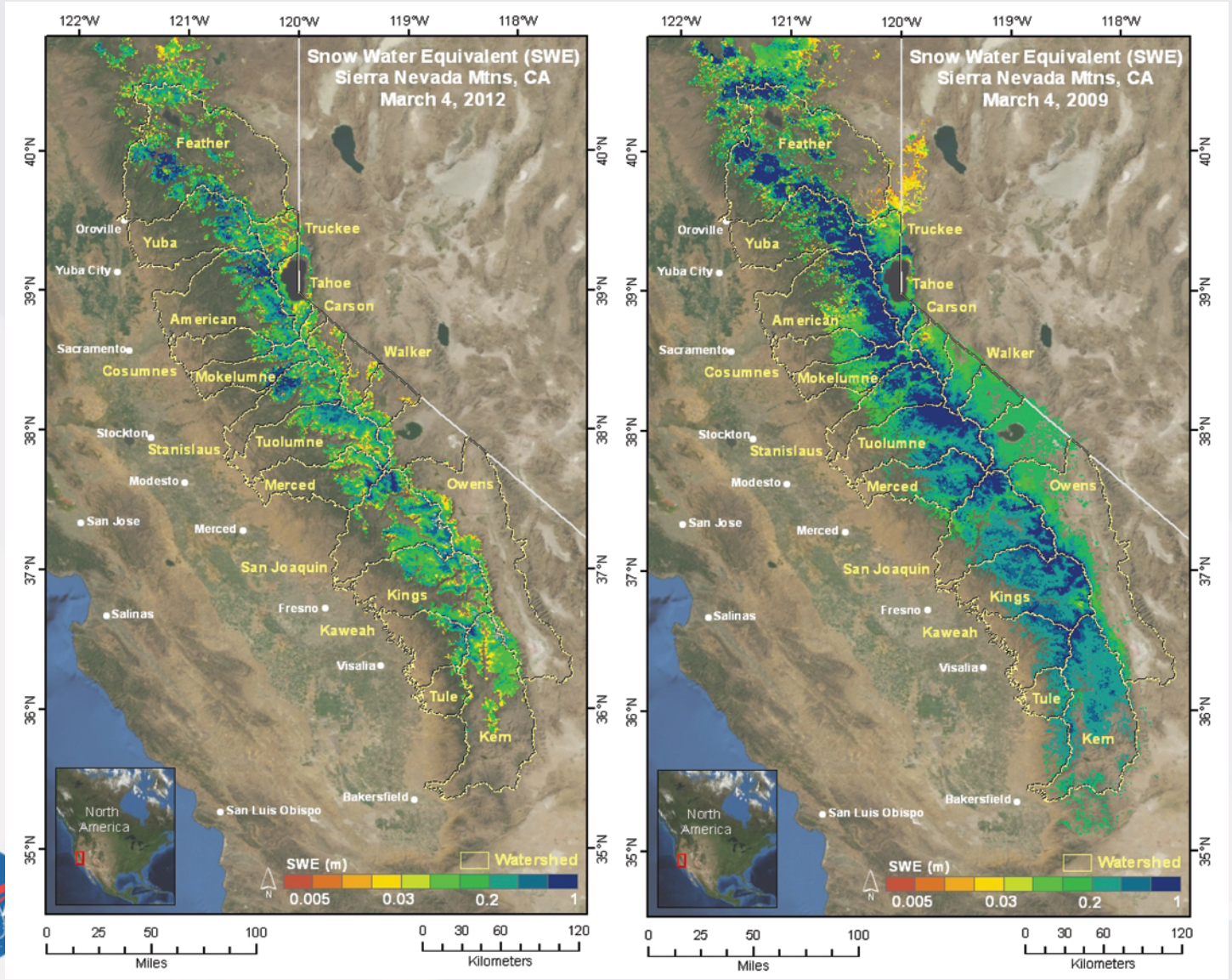
Real Time SWE Reports by Watershed

Watershed	2/5/14 SWE (in)	2/5/14 % Avg to Date
AMERICAN	1.18	9.90
FEATHER	0.03	0.22
KAWEAH	0.64	7.42
KERN	1.01	10.17
KINGS	1.75	10.99
TAHOE	4.39	19.18
MERCED	1.58	13.80
OWENS	0.85	13.75
SAN JOAQUIN	2.55	15.18
STANISLAUS	1.57	10.63
TRUCKEE	1.34	8.63
TUOLUMNE	2.46	16.45
YUBA	0.29	2.53
COSUMNES	0.09	2.77
MOKELUMNE	1.36	12.70
TULE	0.21	3.71
WEST WALKER RIVER	2.43	25.10
EAST WALKER RIVER	2.06	26.16
WEST FORK CARSON RIVER	3.73	25.26
EAST FORK CARSON RIVER	2.89	26.22

Real Time SWE Report by Elevation Band

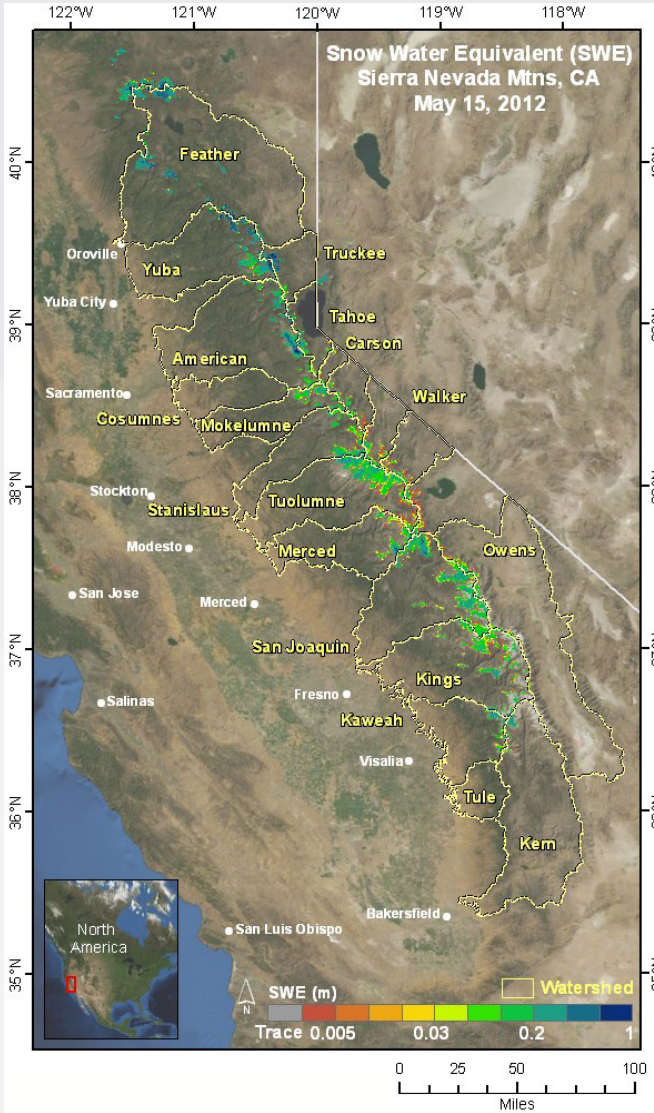
Watershed	Elevation	2/5/14 SWE (in)	2/5/14 % Avg to Date	Area Sq Mi
AMERICAN	3000-4000'	0.00	0.00	191.9
	4000-5000'	0.00	0.09	249.3
	5000-6000'	0.06	0.41	294.8
	6000-7000'	1.81	6.13	296.4
	7000-8000'	6.59	17.75	175.7
	8000-9000'	8.38	20.88	74.2
	9000-10,000'	11.41	23.24	8.9
COSUMNES	3000-4000'	0.00	0.00	77.8
	4000-5000'	0.00	0.00	84.7
	5000-6000'	0.00	0.00	63.6
	6000-7000'	0.57	2.41	28.1
	7000-8000'	5.02	14.48	8.6
E CARSON	5000-6000'	1.32	68.15	32.7
	6000-7000'	1.68	26.83	77.7
	7000-8000'	2.61	24.94	102.6
	8000-9000'	4.01	25.57	96.5
	9000-10,000'	4.42	25.02	29.7
	10,000-11,000'	4.29	25.27	13.5
	> 11,000'	8.15	26.37	0.3
E WALKER	6000-7000'	1.66	44.50	73.6
	7000-8000'	1.43	32.03	157.4
	8000-9000'	1.39	21.80	154.9
	9000-10,000'	2.76	22.53	63.1
	10,000-11,000'	5.33	24.55	48.8
	> 11,000'	6.18	24.31	7.8
FEATHER	3000-4000'	0.00	0.00	286.2
	4000-5000'	0.00	0.00	735.8

Real Time SWE Product: Comparison of Years

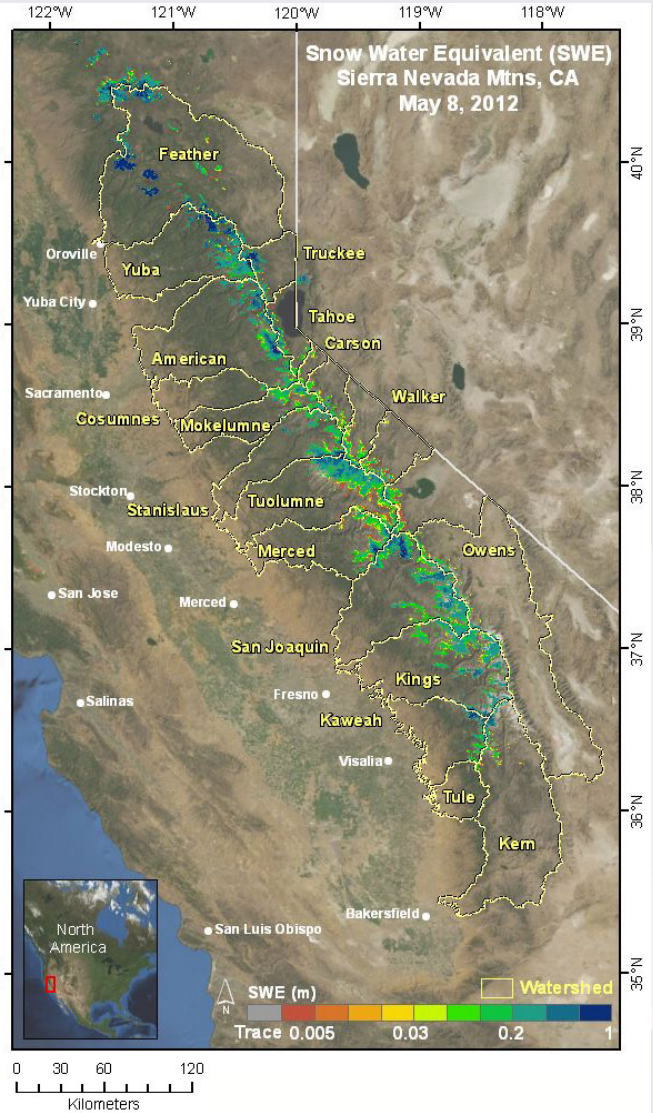


Real-Time SWE: Week to Week

May 15, 2012



May 8, 2012



More Information

- Identify other users / interested parties:

- Water Resources
- Forest Management
- Weather Research
- Regional Climate Modelers

- http://instaar.colorado.edu/mtnhydro/

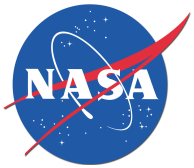
- Noah.molotch@colorado.edu
- Noah.P.Molotch@jpl.nasa.gov

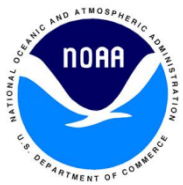
Acknowledgements

NASA: Terrestrial Hydrology & Applications

NSF: Hydrological Sciences

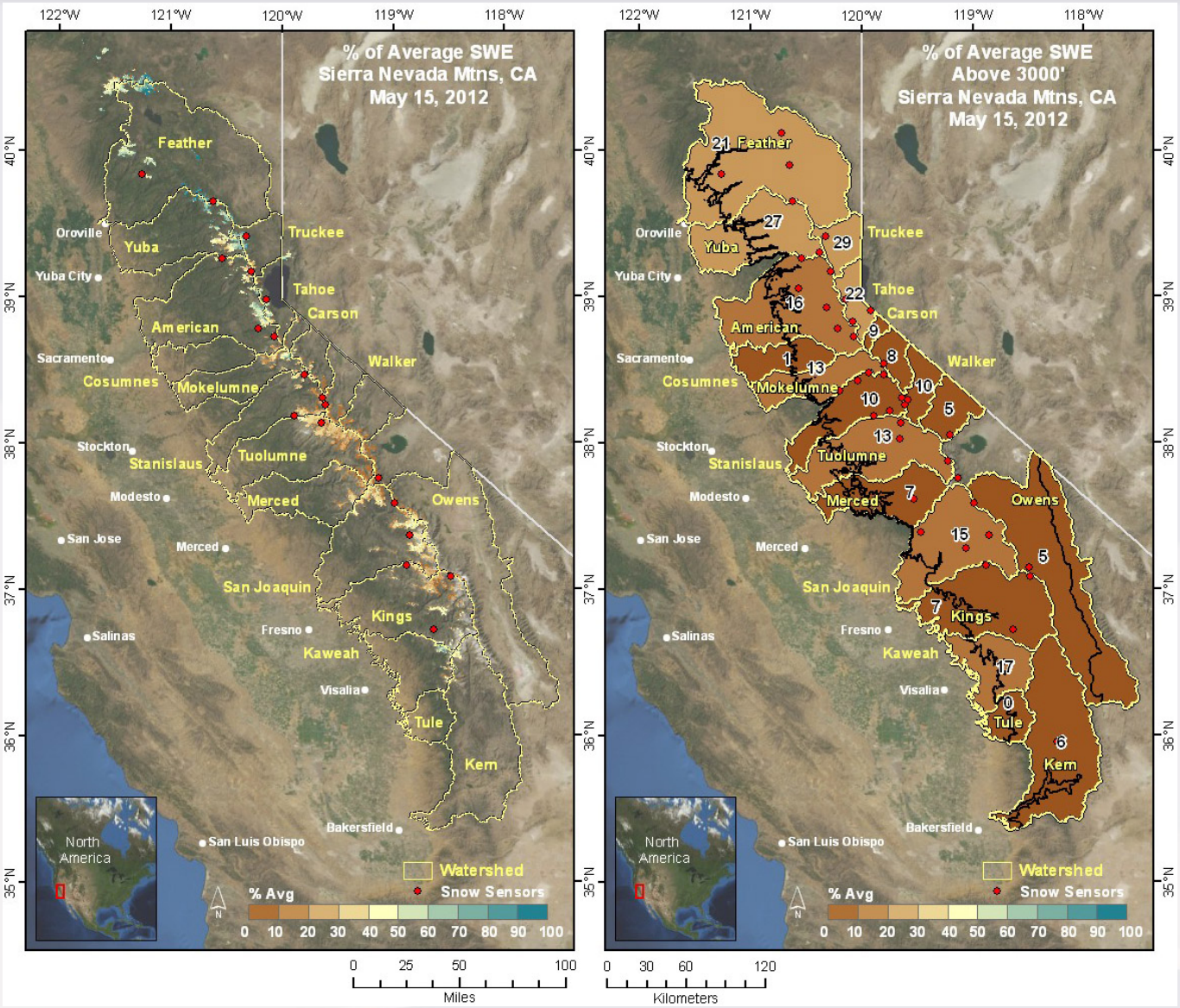
NOAA: Western Water Assessment



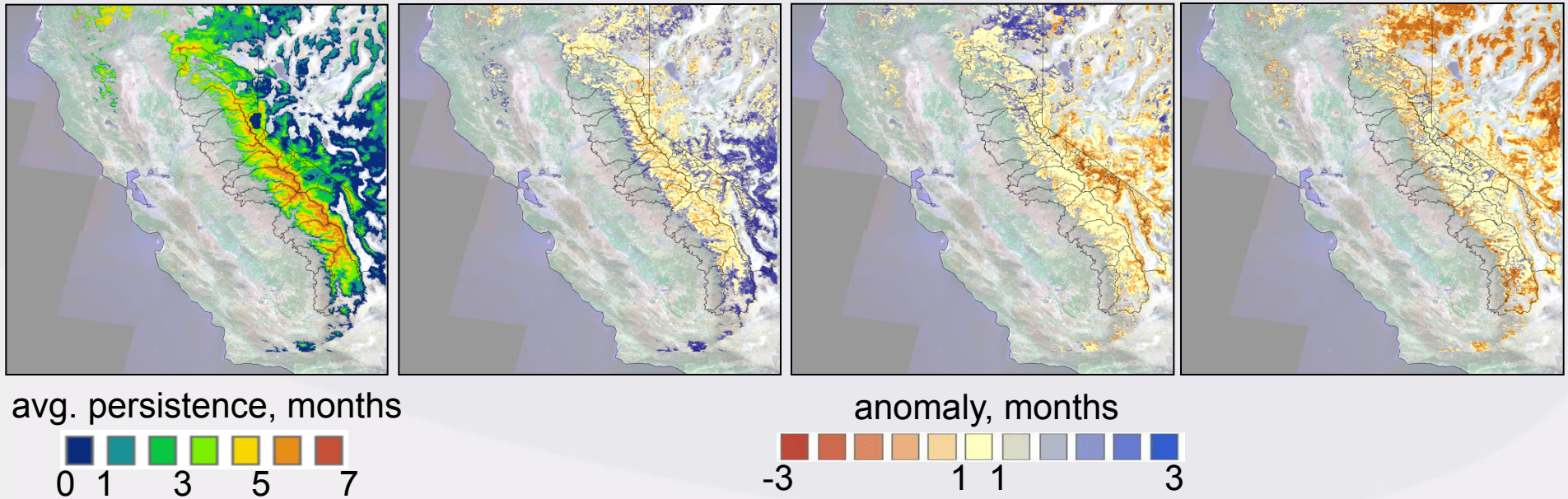


J. Dozier, T. Painter, L. Lestak, B. Guan, D. Schneider, D. Rizzardo, S. Nemeth

Real-Time SWE Anomaly: May 15, 2012

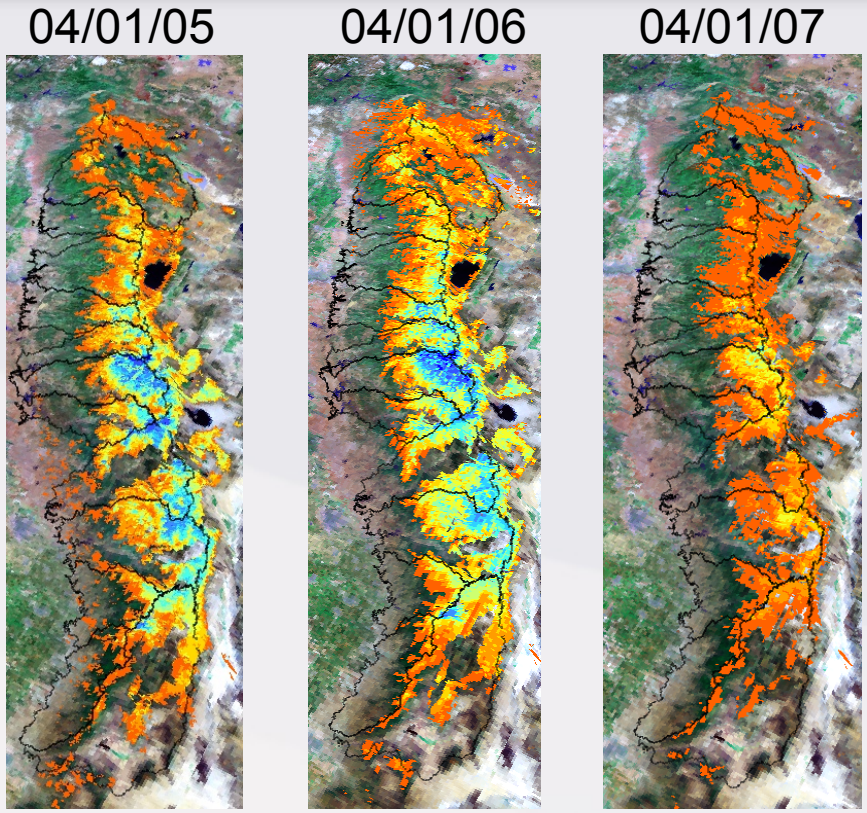


Snow Cover Persistence Anomalies



Molotch et al., in preparatio

Remotely sensed snowpack reconstruction improves Sierra Nevada water storage estimates



MODIS-model estimates of snow water equivalent in Sierra Nevada reveal extreme inter-annual variability.

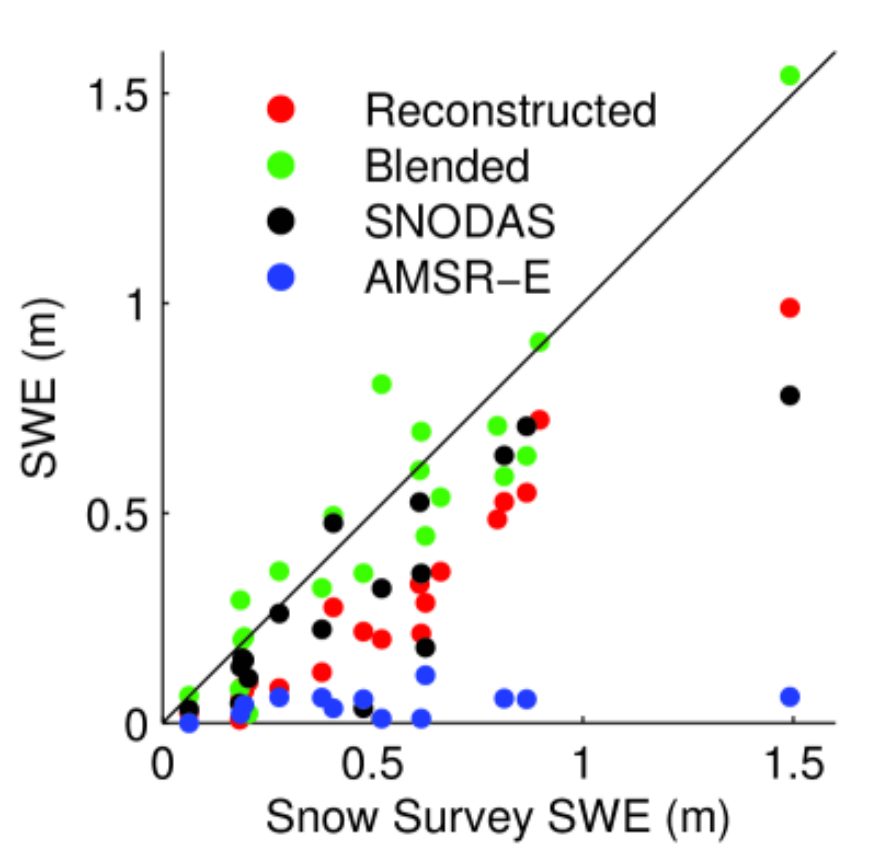
Molotch, 2009

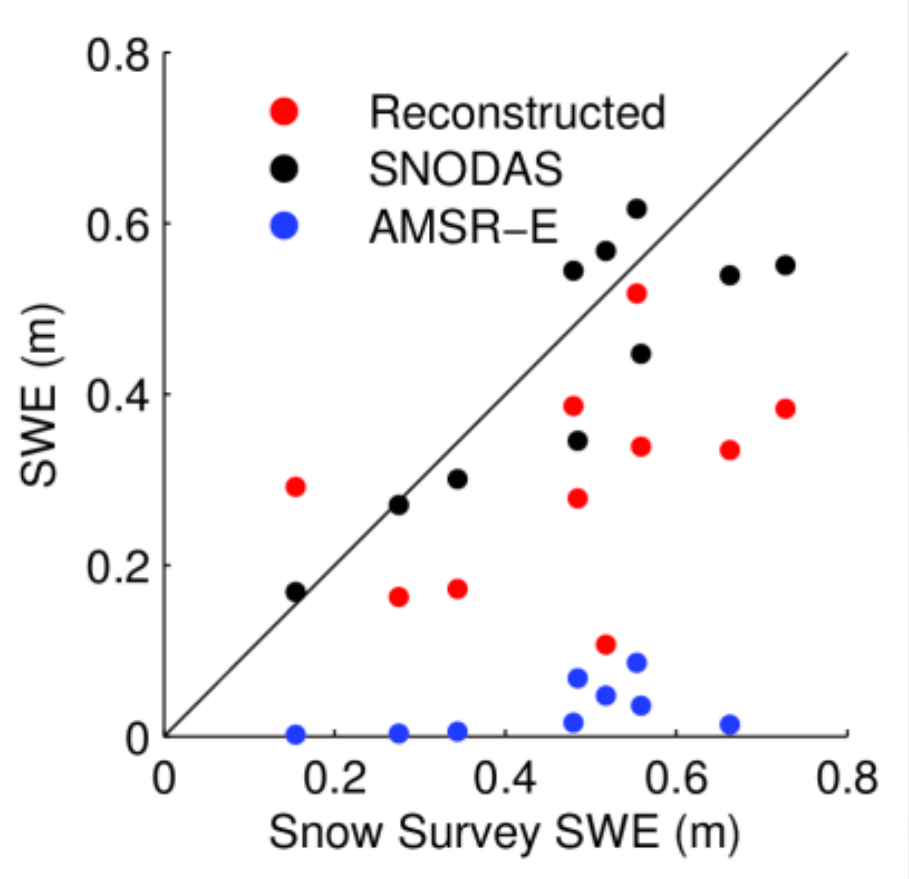
Product: **Merged MODIS snow data with models to map SWE across Sierra Nevada.**

Maturity: Algorithm has been published through series of papers: Molotch et al 2004; Molotch & Bales, 2005, 2006; Molotch & Margulis, 2008; Molotch, 2009; Dozier et al., 2008. Products under development for Sierra Nevada.

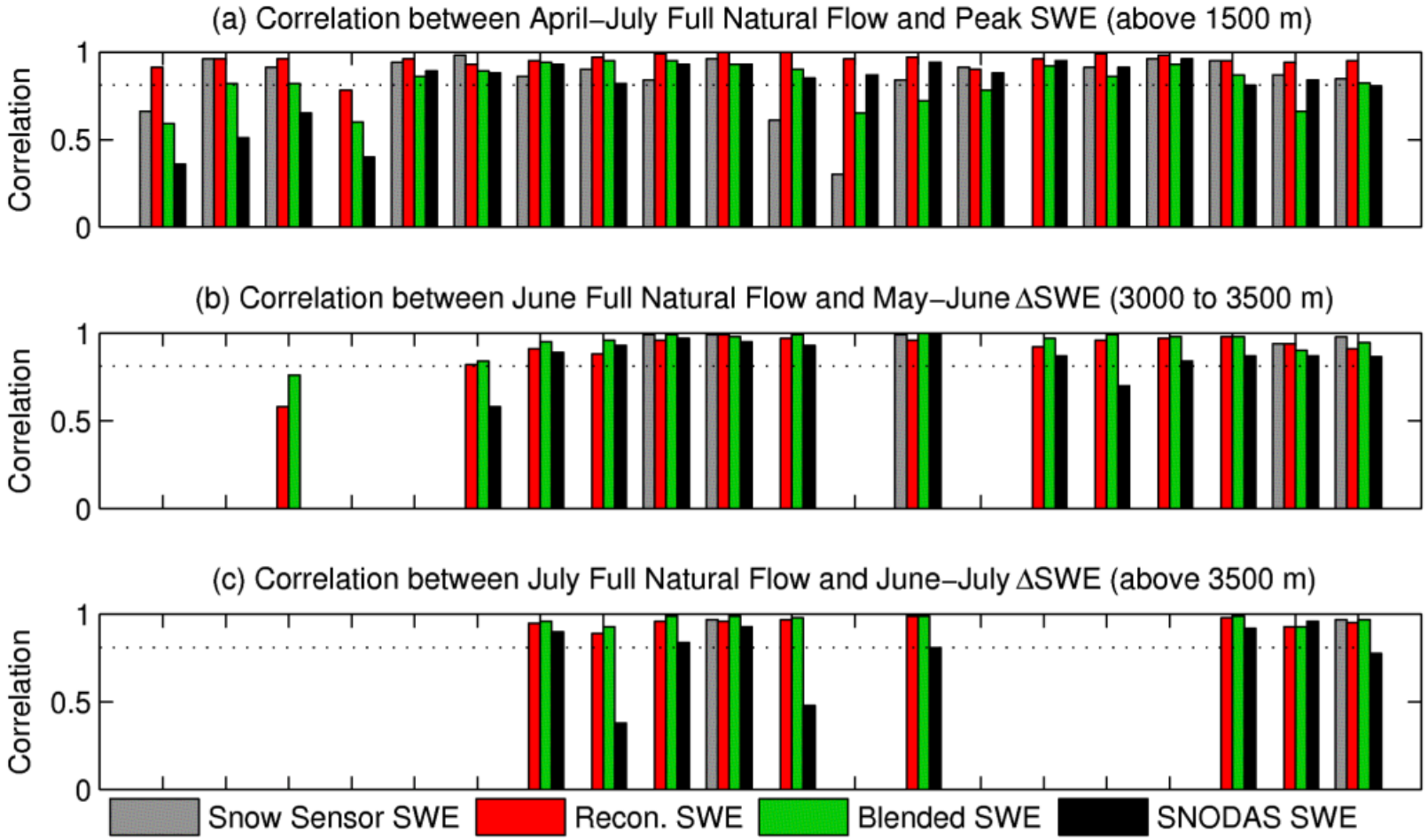
Earlier development dates back to 1970's with Al Rango and Jaroslov Martinec.

Model Performance



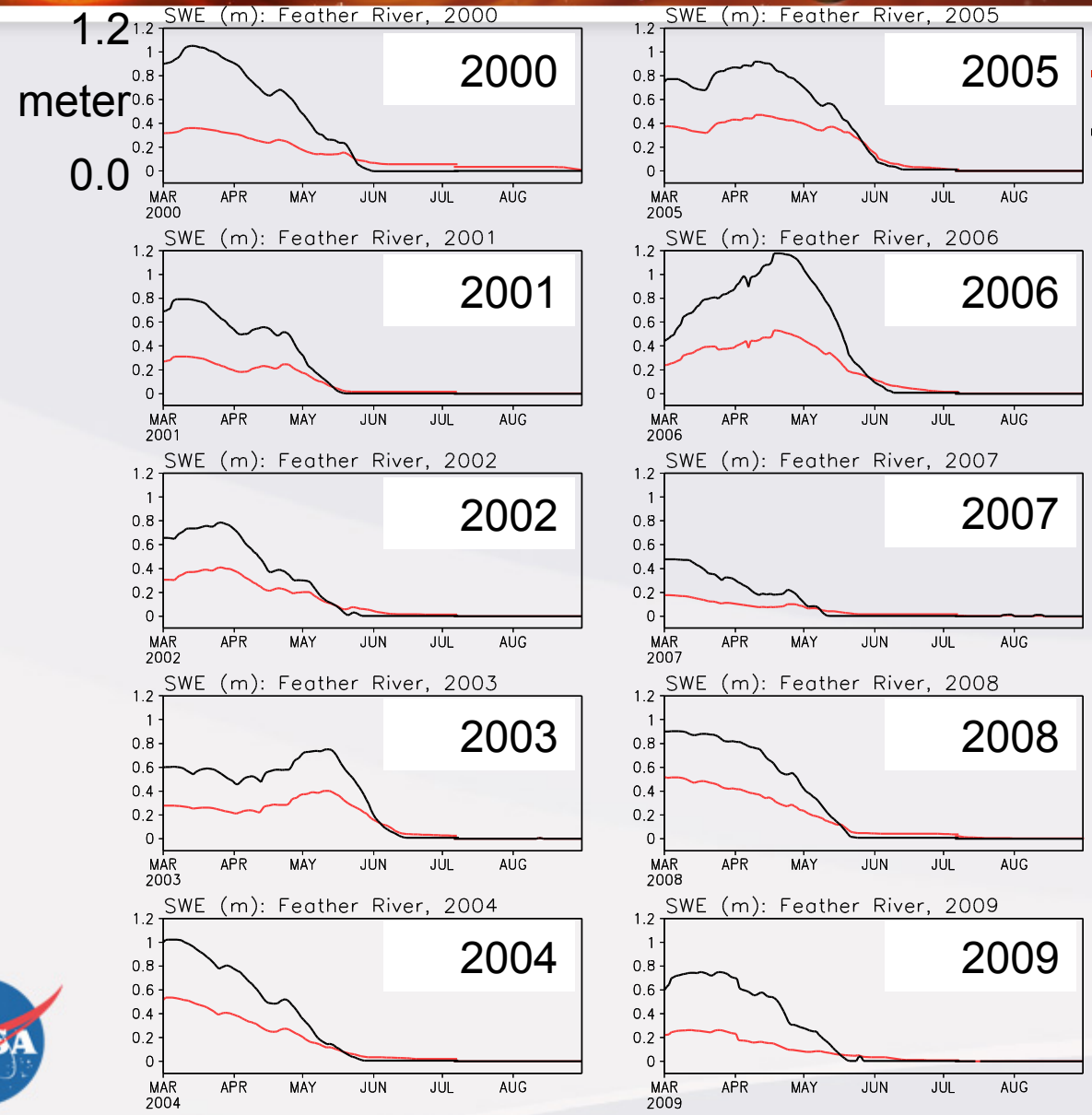


Correlation with Natural Flow: Sierra Nevada



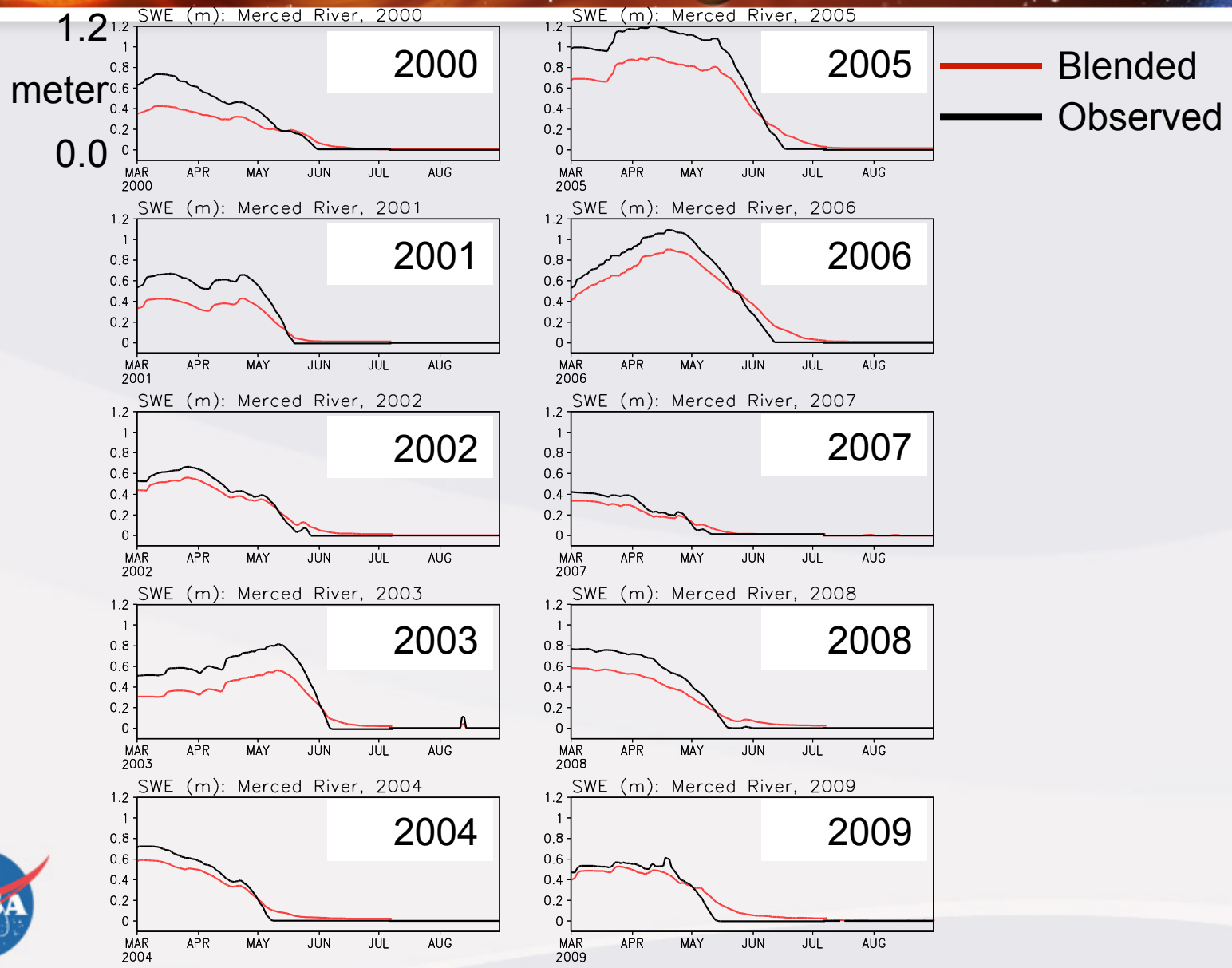
Guan et al., in review.

Mean Watershed SWE: Feather River

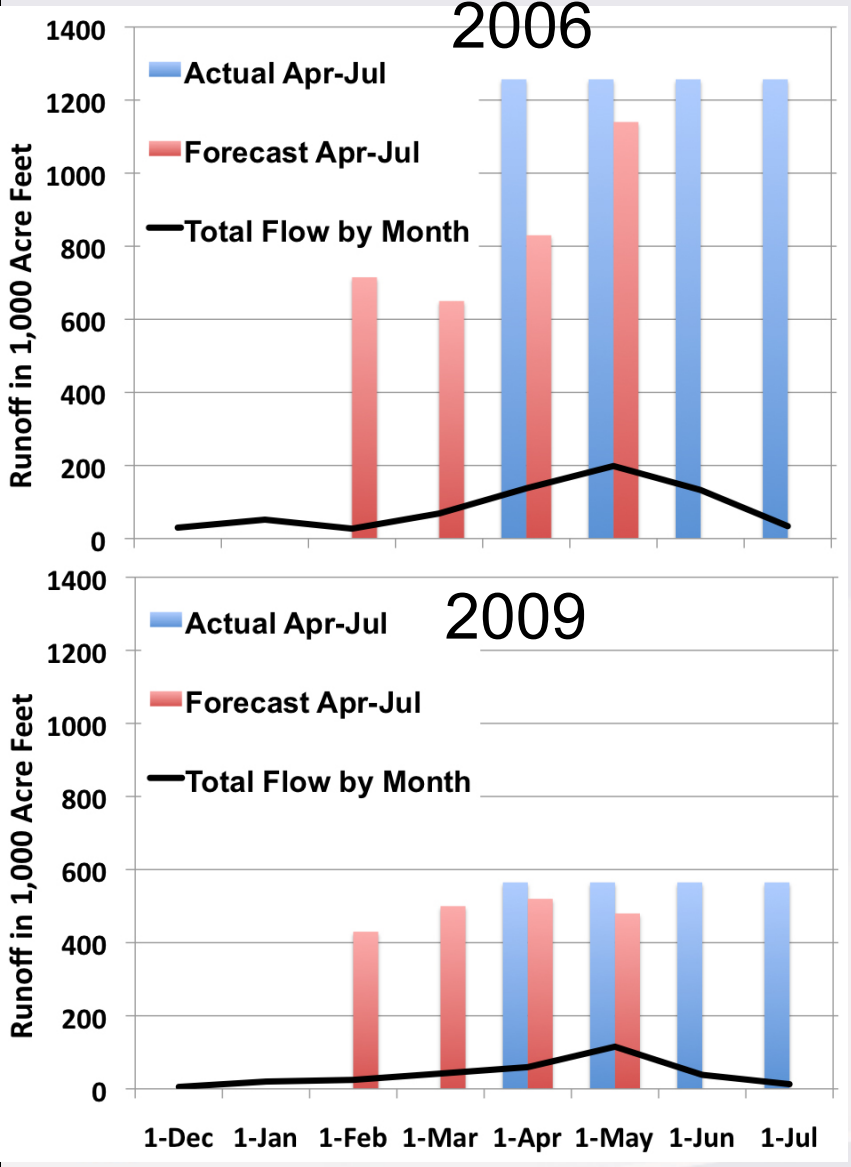


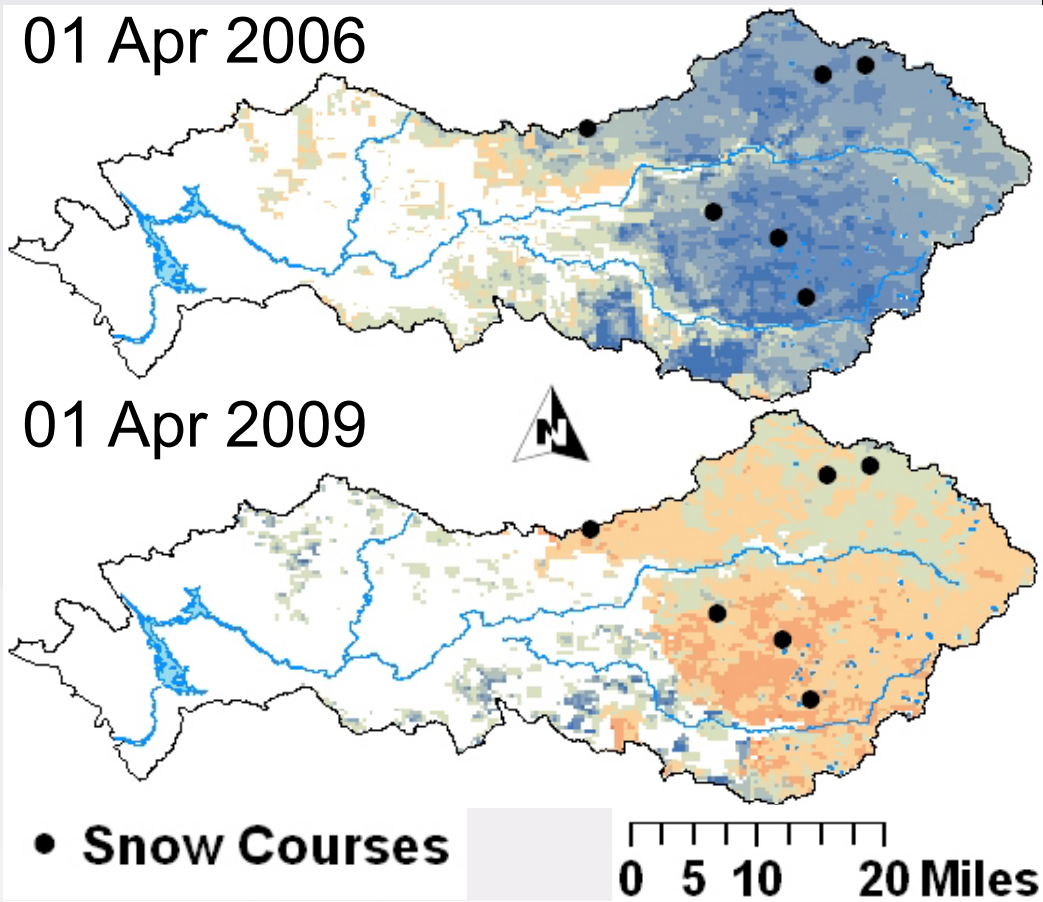
Blended SWE=SNODIS-Distributed Residual

Mean Watershed SWE: Merced River



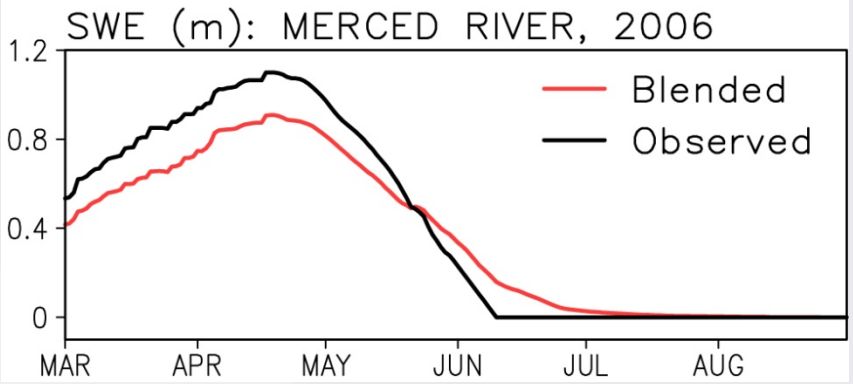
Unimpaired Flow Merced R. at Merced Falls



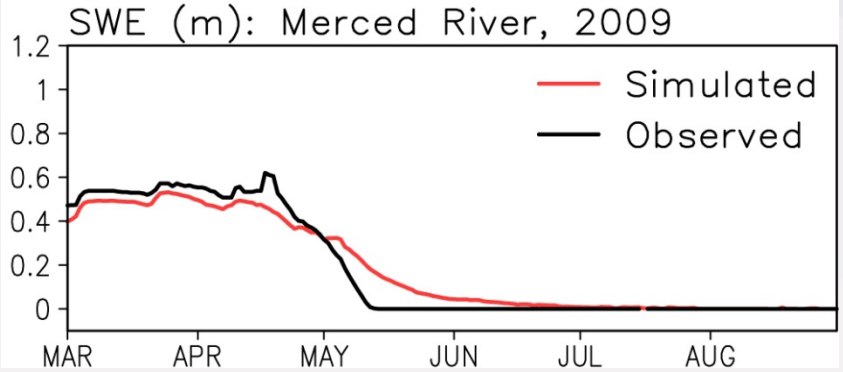


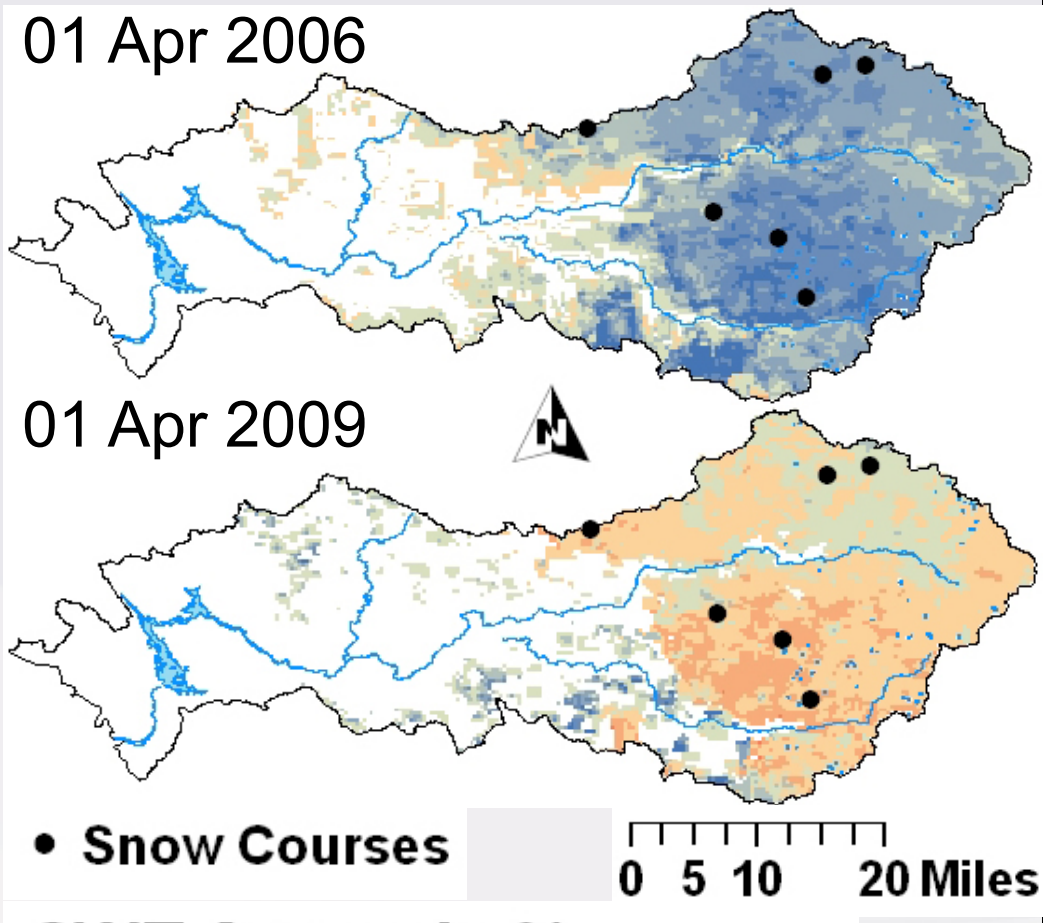
Merced Basin - Snow Pillows vs. Spatial SWE

2006

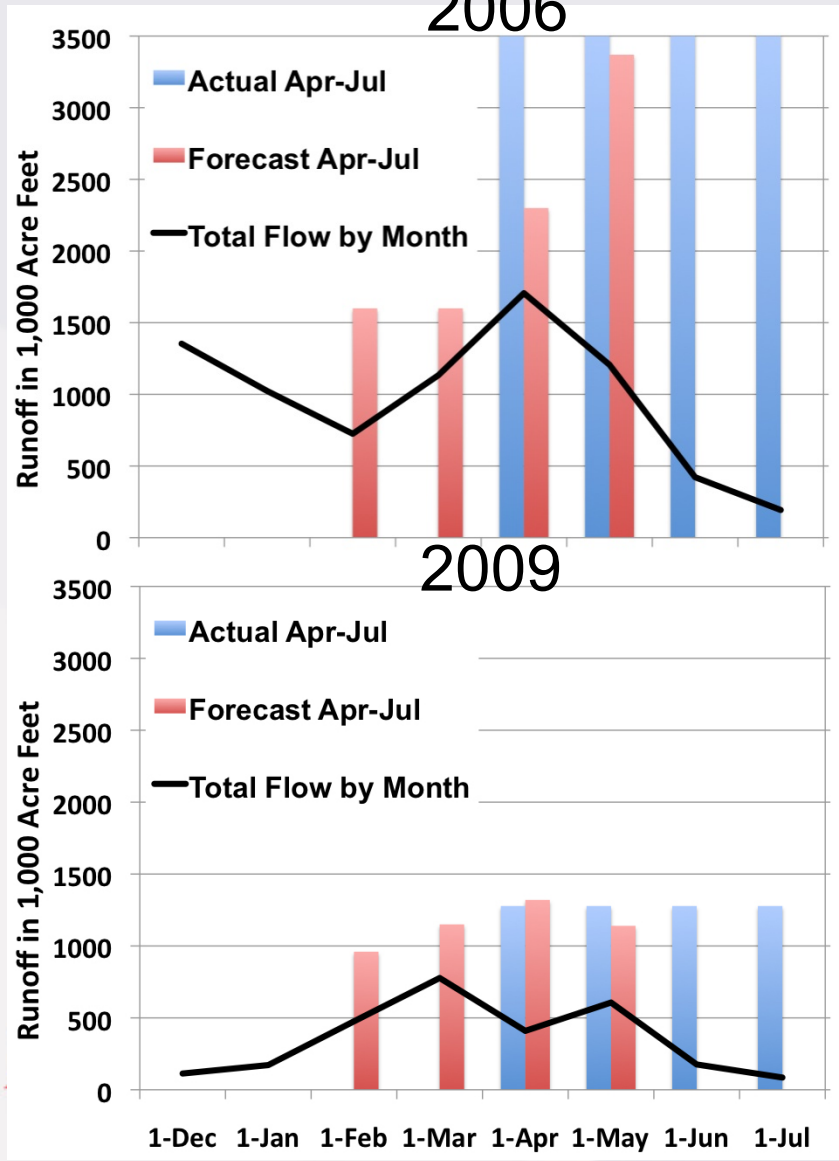


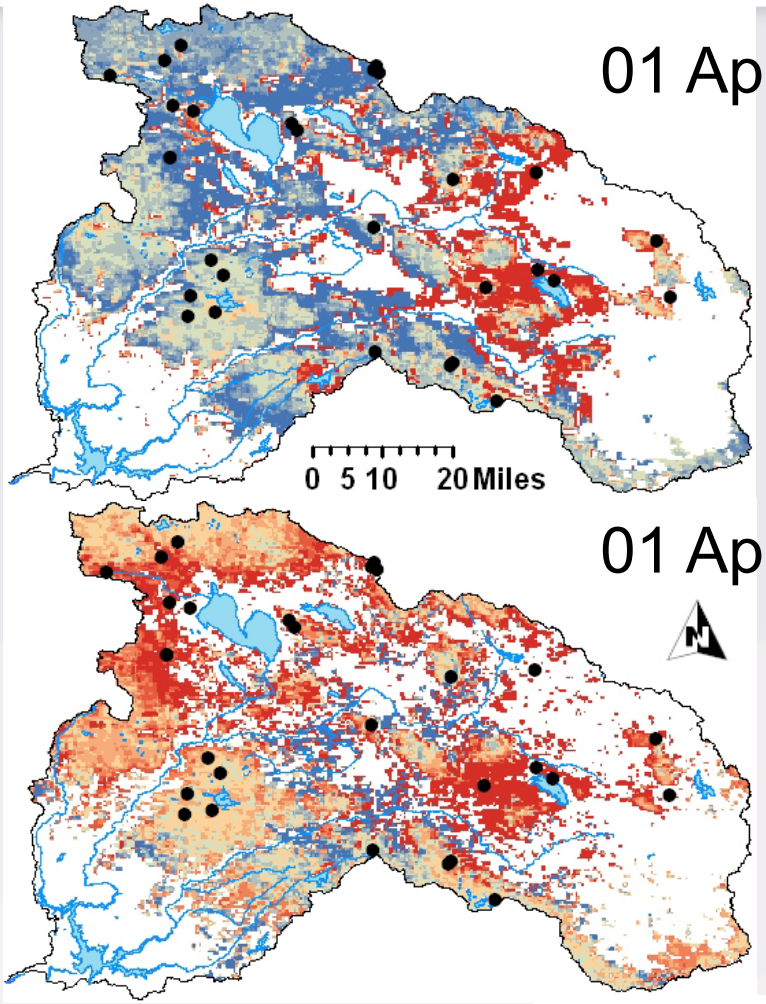
2009





Unimpaired Flow Feather R. to Lake Oroville





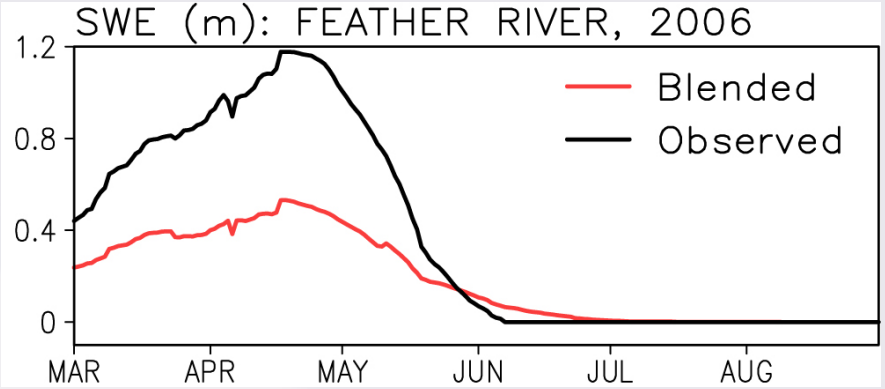
SWE Anomaly %

• Snow Courses

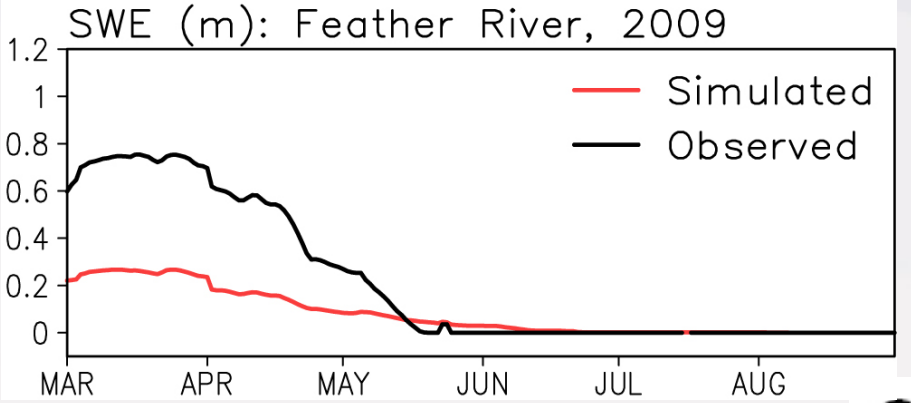
-100 -60 0 60 100

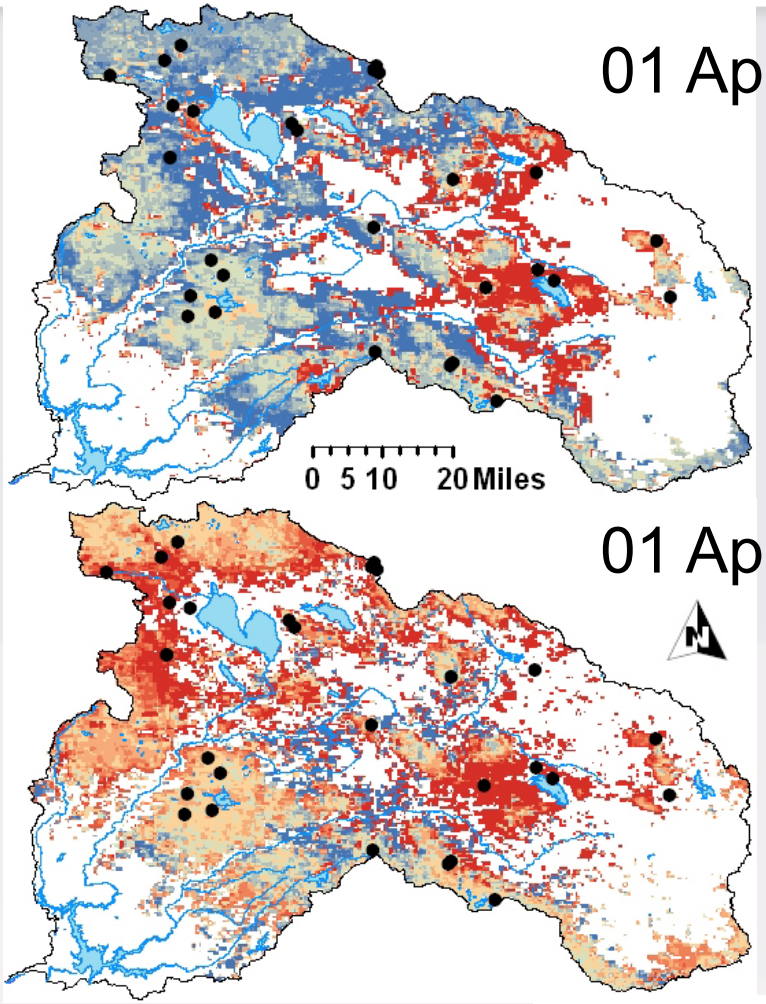
Feather Basin - Snow Pillows vs. Spatial SWE

2006



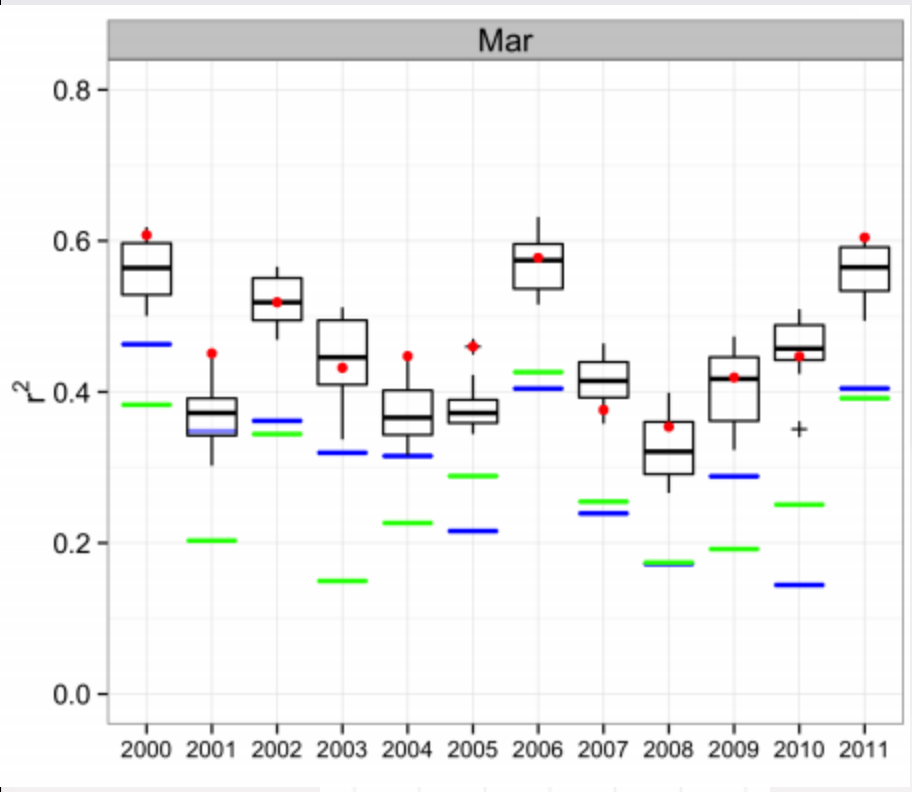
2009

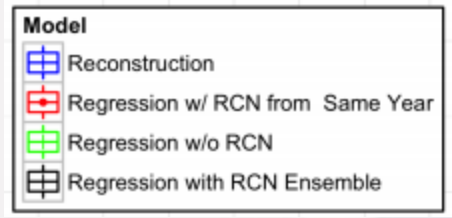




Multi-variate Regression: SWE Interpolation

Annual Performance





Multi-Year Performance